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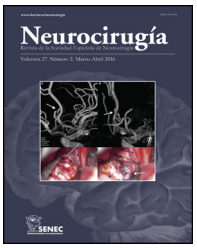

Clinical Research

3D printing in neurosurgery: A specific model for patients with craniosynostosis☆

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ABSTRACT

Introduction: Craniosynostosis is a rare condition and requires a personalised surgical approach, which is why we consider the use of 3D printed models beneficial in the surgical planning of this procedure.

Material and methods: Acrylonitrile butadiene styrene plastic skull models were designed and printed from CT images of patients between 3 and 6 months of age with craniosynostosis of different sutures. The models were used to simulate surgical procedures.

Results: Four models of four patients with craniosynostosis were produced: two with closure of the metopic suture and two with sagittal suture closure. The mean age of the patients was 5 months (3–6 m) and the mean duration of the surgery was 286 min (127–380 min).

The acrylonitrile butadiene styrene plastic models printed for the project proved to be optimal for the simulation of craniosynostosis surgeries, both anatomically and in terms of mechanical properties and reaction to surgical instruments.

Conclusions: 3D printers have a wide range of medical applications and they offer an easy and affordable way to produce skull models. The acrylonitrile butadiene styrene material is suitable for the production of operable bone models as it faithfully reproduces the mechanical characteristics of bone tissue.

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Impresión 3D en neurocirugía: modelo específico para pacientes con craneosinostosis

Palabras clave:
Impresión 3 D
Neurocirugía
Craneosinostosis
Planificación quirúrgica

RESUMEN

Introducción: La patología de craneosinostosis es infrecuente y requiere una intervención quirúrgica muy individualizada, por lo que consideramos que la práctica con modelos impresos 3 D podría ser beneficiosa en la planificación quirúrgica de esta patología.

Material y métodos: Diseño e impresión de modelos de cráneo en plástico *acrylonitrile butadiene styrene* a partir de las imágenes de TAC de pacientes entre 3 y 6 meses de edad con craneosinostosis de diferentes suturas, y reproducción de las intervenciones quirúrgicas sobre los modelos.

Resultados: Se realizaron 4 modelos de 4 pacientes con craneosinostosis: 2 con cierre de la sutura metópica y 2 de sutura sagital. La edad media de los pacientes fueron 5 meses (3-6 m) y la duración media de la cirugía 286 min (380-127 min).

El modelo impreso en plástico *acrylonitrile butadiene styrene* para el proyecto resultó óptimo para la simulación de las cirugías de craneosinostosis, tanto anatómicamente como en cuanto a propiedades mecánicas y reacción al instrumental quirúrgico.

Conclusiones: Las impresoras 3 D tienen un amplio abanico de aplicaciones médicas. Es posible realizar un modelo de cráneo de forma sencilla y asequible. El material *acrylonitrile butadiene styrene* es adecuado para la realización de modelos de hueso operables, pues reproduce fielmente las características mecánicas óseas.

Introduction

The use of 3D printing in the field of biotechnology has grown significantly over recent years. The aim of this technology is to fabricate three-dimensional objects in a simple way, requiring only a printer and computer-aided design software.[1]

Its applications in the field of neurosurgery can be divided into 3 groups: anatomical models, models that simulate patient-specific pathology and creation of biocompatible prostheses.[2]

Of all the pathologies that may benefit from 3D printing, we have decided that craniosynostosis is the pathology of greatest interest, as it requires a personalised surgical approach.

Craniosynostosis refers to the premature fusion of one or more of the cranial sutures, resulting in an abnormal head shape. Growth of the skull is restricted perpendicular to the fused suture and exaggerated parallel to the suture. As a result, not only is cranial deformity observed, but brain growth may also be restricted.[3]

The three most common types of craniosynostosis are: scaphocephaly due to closure of the sagittal suture, trigonocephaly due to closure of the metopic suture and anterior plagiocephaly due to unilateral closure of the coronal suture.[3,4] Each type results in different cranial deformities and potential long-term consequences if not treated, and therefore a surgical approach is currently used to treat them.

Surgery is indicated for both aesthetic and functional reasons, since these patients may develop increased intracranial pressure as well as visual and cognitive impairments in the future.[5]

Material and methods

In 2015, the Medical Engineering laboratory was founded as part of the Faculty of Medicine of the Universidad de Navarra. The idea was to promote collaboration between different areas with a common interest, including the department of neurosurgery.

We acquired a 3D printer (Wanhao Duplicator 4S) and then looked into the possibility of creating anatomical models using different materials for teaching purposes and to help plan surgeries for various pathologies. None of the authors involved in this article have any conflicts of interest.

We chose craniosynostosis as the neurosurgical bone pathology to study as it is a surgery with multiple variables and it is unique to each patient. Skull models were created for patients with craniosynostosis who were going to undergo surgery and who had previously had a diagnostic head CT scan. Clinical data for these patients were collected. The parents of all the patients received information on what was going to be done, and they all signed an informed consent form in compliance with the Declaration of Helsinki. The model was made a few days before surgery.

Computed tomography images were processed using 3D Slicer software to extract only those data corresponding to bone density, thereby obtaining an image of the patient's skull.

The images were then processed using Rhino 5 and the STL file was cut using Meshmixer software (Autodesk) (Fig. 1).

After finalising the design, the model obtained was printed using a Wanhao Duplicator 4S, which works by depositing molten material and takes 8 h.